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Evaluating herbicide resistance in *Rumex* spp. and its management in wheat (*Triticum aestivum*)

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ABSTRACT

Wheat (*Triticum aestivum* L.) crop grown with rice-wheat cropping system is infested with complex weed flora. *Rumex* spp. is the major broad-leaf weed of wheat crop wherein the poor efficacy of recommended herbicides and likelihood of herbicide resistance has been noticed. Hence, two herbicides - metsulfuron (X dose- 4g a.i/ha) and halauxifen + fluroxypyr (X dose- 240 g a.i/ha) applied at three doses (0.5X, X and 2.0X) were evaluated against four populations of *Rumex* spp. in a pot experiment carried out at screen house of college of Agriculture, CCS HAU, Hisar during *rabi* 2017–18. One unsprayed control was also kept for each population and herbicide for comparison. Results indicated that majority of the *Rumex* biotypes have attained resistance against metsulfuron and were not controlled even at double of the recommended dose. Higher values of plant height, chlorophyll fluorescence, fresh weight and dry weight and lower value of electrical conductivity was observed in the herbicidal treatments showing comparatively less efficacy against this weed. All *Rumex* biotypes were found highly sensitive to halauxifen + fluroxypyr at recommended dose and recorded 85–90% visual mortality. The application of halauxifen + fluroxypyr is the best alternative option to manage this weed in problematic areas.

Keywords: Chlorophyll fluorescence, Electrical conductivity, Halauxifen + fluroxypyr, Metsulfuron

Wheat (*Triticum aestivum* L.) is the world's most widely cultivated and leading staple food crop grown in an area of 214.3 million ha (mha) with production and productivity of 734.1 million tonnes (mt) and 3425.5 kg/ha, respectively (FAO STAT 2018). Haryana is a major wheat producing state which produces nearly 11.7 mt of wheat grains with productivity of 4.62 t/ha from an area of 2.53 mha (Anonymous 2018a). Yield loss in wheat due to weeds range from 15–50% and untreated weeds can cause up to 60% yield drop (Singh *et al.* 2015). Reduced tillage or no-till wheat though mitigates the problem of grassy weeds like *Phalaris minor* but shift towards broad leaf weeds like *Malwa parviflora* and *Rumex* spp. happen under this conservation practice. Among these, *Rumex* spp. (toothed dock) is a major one reducing the crop yield up to 55% in wheat crop (Balyan and Malik 2000). Chemical methods are most widely used for effective and economic weed management (Gracia Martin *et al.* 2007). Metsulfuron, a sulfonylurea herbicide, is recommended herbicide for the control of broad leaf weeds including *Rumex* spp. in wheat crop. But recently in India, few reports have highlighted that *Rumex* spp. has evolved resistance under field conditions against Group B/2 herbicides known as ALS inhibitors (Inhibition of acetolactate synthase). In India it is the second case of herbicide resistance and first among broadleaf weeds (Chhokar *et al.* 2013, 2017).

Presently, herbicide combinations including tank mix or sequential application have shown improved weed control efficiency and broad spectrum control of resistant weeds (Singh, 2015 and Kaur 2017). The different herbicide mixtures such as fenoxaprop + metribuzin, halauxifen + florasulum also effectively controls the broadleaf weeds including *Rumex* spp. in wheat (Walia *et al.* 2011, Chhokar *et al.* 2015, Punia *et al.* 2017, and Sivran *et al.* 2020). In this backdrop, there is apparent need to identify alternate herbicides for its management and generate information for the follow up studies for their likely use in the management of other broad leaf weeds and integration with grassy herbicides so that the problem of herbicide resistance may be tackled effectively.

MATERIALS AND METHODS

Survey and collection of resistant biotyes of Rumex *spp.*: Seeds of *Rumex* spp. were collected from putative resistance affected farmer's fields as revealed by initial reports and feedback provided by the scientists working in respective Krishi Vigyan Kendras (2017–18). As per their location, these populations were named as HHH (HAU,

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Hisar), UPH (Ujha, Panipat), JHH (Jind) and JJH (Jhajjar) biotype and findings are interpreted accordingly.

Experimental setup and treatment details: Two herbicides - metsulfuron (X dose- 4g a.i/ha) and halauxifen + fluroxypyr (X dose- 240g a.i/ha) applied at three doses (0.5X, X and 2.0X) were evaluated against four populations of *Rumex* spp. in a pot experiment carried out at screen house of college of Agriculture, CCSHAU, Hisar during *rabi* of 2017-18 under Completely Randomised Design (CRD) replicated thrice. Each herbicide constituted one set of experiment (three in total) comprising four populations, three doses and three replications. Untreated check was also maintained for comparison purpose.

The air dried and crushed soil passed through a sieve of 2 mm pore size was used for filling the pots while ensuring that it is free from seeds of *Rumex* spp. and also not subjected to any herbicide application from the last two years. Plastic pots (6″ diameter) of 2 kg capacity were filled up with sand, field soil and vermi-compost in the ratio of 2:3:1. Fifteen seeds each of collected biotypes of *Rumex* were sown on 27th December, 2017 at a depth of 3-4 cm under optimum moisture condition. After the emergence, thinning was done to maintain a uniform plant population of 10 seedlings/per pot for defined herbicide treatments. The plants were sprayed at 38 days after sowing (DAS). Harvesting was done at 120 DAS on 26 April, 2018.

Morphometric observations

Plant height: The plant height (cm) was measured from the soil surface to the tip of fully opened leaf at 4 weeks after treatment (WAT). The said observation was recorded from three plants in each pot.

Electrical Conductivity (EC): The value of EC was taken at 4 WAT. The EC values tend to be on lower side with reduced herbicide efficacy on weeds. Individual weed samples were placed in flasks containing distilled water (50 ml) for one day, and then boiled to specific temperature so that salt of samples dissolves in distilled water. Then EC reading was taken using EC meter.

Chlorophyll fluorescence: The value of chlorophyll fluorescence (Fv/Fm) were taken at 7 DAT (days after treatment) with the help of Hansatech chlorophyll fluorescence meter. In chlorophyll fluorescence meter, clips were used for dark adaptation. At first, these clips were fitted on leaves for 20 min period. Then these clips were hooked on chlorophyll fluorescence meter to record the chlorophyll fluorescence of leaves where the clips were initially fitted. The lower efficacy of herbicides results in higher values and vice-versa.

Per cent control: Per cent control of *Rumex* spp. was recorded visually at 4 WAT by comparing each treatment with unsprayed control. Rating was done in 0-100 scale (0 means no control and 100 means complete control of *Rumex* spp.).

Fresh and dry weight: All the weed plants present in each pot were harvested at 120 DAS and fresh weight was taken. Thereafter, these plants were first dried under the sun light and then kept in oven at 65±5^{0}C till a constant weight was achieved. The dried samples were weighed. The fresh and dry weight was expressed as g/pot.

Statistical analysis: All the observations were statistically analyzed by using software OP STAT version 6.1. Angular (Arcsine) transformationwas used in per cent control data of weeds using the formula:

Arcsine transformation = ARSIN [SQRT (germination/100)] × 90/1.571

RESULTS AND DISCUSSION

Metsulfuron dose-response studies: The data on metsulfuron dose-response studies is presented in Table 1. Across different doses of metsulfuron, significantly higher plant height (24.8 cm) and higher chlorophyll fluorescence (0.85) was observed in UPH biotype followed by JHH, HHH and JJH, respectively. When compared with recommended/X dose, metsulfuron applied at 0.5X resulted in 10% higher plant height and 7.2% higher plant chlorophyll fluorescence, whereas suppressed plants (11.3%) and lower chlorophyll fluorescence (10.1%) was observed at 2X dose. Significantly lower EC was observed in UPH (0.06 dS/m) followed by JHH (0.09 dS/m), HHH (0.27 dS/m) and JJH (0.29 dS/m). Significantly lower mortality was recorded in UPH (18%) followed by JHH (31%), HHH (50%) and JJH (60%). The plant mortality in each of the four populations increased with increase in herbicide dose from 0.5X to 2X.When data were averaged over metsulfuron doses, significantly higher fresh weight (g/pot) was recorded in UPH (7.17) followed by JHH (5.19), HHH (2.7) and JJH (1.29), whereas significantly higher dry weight (g/pot) was recorded in UPH (2.67) followed by JHH (1.90), HHH (1.00) and JJH (0.87) at harvest (120 DAS). The fresh and dry weight showed decreasing trend with increase in dose of herbicide over all biotypes.

UPH, JHH and HHH biotype showed poor control against metsulfuron at 05X, X and 2X dose but good control was observed in case of JJH biotype at 2X dose. Due to high degree of tolerance to metsulfuron, UPH and JHH biotypes showed lowest control. Therefore, these biotypes attained higher plant height, chlorophyll fluorescence, fresh and dry weight as compared to other biotypes. Lowest EC was recorded in UPH and JHH biotype which again confirms the likely resistance in these weed biotypes against metsulfuron. These results are in conformity with findings of Chhokar *et al.* (2017), Yadav *et al.* (2017) and Singh *et al.* (2017).

Halauxifen + fluroxypyr dose-response studies: As per mean data of halauxifen + fluroxypyr doses, significantly higher plant height (cm) was recorded in UPH and JHH (18.1) which was at par with HHH (17.4) but significantly higher than JJH (14.5) at 4 WAT. Similarly higher plant chlorophyll fluorescence (Fv/Fm) was observed in JJH (0.61) followed by UPH (0.54), JHH (0.44), HHH (0.41) at 7 DAT. Mean plant chlorophyll fluorescence of HHH was found statistically at par with JHH at 7 DAT. Half dose of halauxifen + fluroxypyr resulted in 6.3% higher plant height and 5.1% higher plant chlorophyll fluorescence over recommended dose, whereas double dose resulted in

Table 1 Plant height, chlorophyll fluorescence, electrical conductivity, per cent control, fresh and dry weight of *Rumex* biotypes as influenced by application of metsulfuron

Biotype	Metsulfuron																													
	Plant height (cm) at 4 WAT					Chlorophyll fluorescence (Fv/Fm) at 7 DAT					Electrical conductivity (dS/m) at 4 WAT					Mortality (%) at 4 WAT					Fresh weight at 120 DAS					Dry weight at 120 DAS				
	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	**0**	0.5X	X	2X	Mean
HHH	26.3	20.7	18.3	16.3	20.4	0.85	0.64	0.61	0.50	0.65	0.02	0.27	0.30	0.47	0.27	0 (0)	57 (70)	62 (78)	81 (97)	50 (61)	6.97	2.07	1.73	0.33	2.78	2.47	0.77	0.63	0.13	1.00
UPH	27.3	26.0	24.3	21.3	24.8	0.91	0.86	0.84	0.78	0.85	0.03	0.05	0.07	0.10	0.06	0 (0)	18 (10)	24 (17)	28 (22)	18 (12)	8.57	7.10	6.70	6.30	7.17	3.23	2.70	2.43	2.30	2.67
JHH	27.7	24.3	22.0	19.0	23.3	0.91	0.81	0.75	0.69	0.79	0.03	0.08	0.11	0.14	0.09	0 (0)	38 (38)	41 (43)	43 (47)	31 (32)	7.63	4.80	4.30	4.03	5.19	2.83	1.73	1.57	1.47	1.90
JJH	21.7	18.0	16.7	15.3	17.9	0.84	0.65	0.56	0.52	0.64	0.03	0.30	0.39	0.44	0.29	0 (0)	75 (93)	81 (97)	85 (98)	60 (72)	3.23	0.80	0.60	0.53	1.29	2.40	0.43	0.33	0.30	0.87
Mean	25.8	22.3	20.3	18.0		0.88	0.74	0.69	0.62		0.03	0.17	0.22	0.29		0 (0)	47 (53)	52 (59)	59 (66)		6.60	3.69	3.33	2.80		2.73	1.41	1.24	1.05	
	CD (P=0.05)			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*	
Biotypes	0.8			0.28		0.01			0.004		0.02			0.006		3			1.13		0.32			0.109		0.15			0.052	
Herbicide	0.8			0.28		0.01			0.004		0.02			0.006		3			1.13		0.32			0.109		0.15			0.052	
Biotypes × herbicide	1.6			0.56		0.02			0.008		0.04			0.012		7			2.26		0.63			0.217		0.30			0.104	

Original figures in parenthesis were subjected to angular transformation. X dose is 4g/ha; WAT, weeks after treatment, DAT, days after treatment.

Table 2 Plant height, chlorophyll fluorescence, electrical conductivity, per cent control, fresh and dry weight of *Rumex* biotypes as influenced by the application of halauxifen + fluroxypyr

Biotype	Halauxifen + fluroxypyr																										
	Plant height (cm) at 4 WAT					Chlorophyll fluorescence (Fv/Fm) at 7 DAT					Electrical conductivity (dS/m) at 4 WAT					Mortality (%) at 4 WAT					Fresh weight at 120 DAS					Dry weight at 120 DAS				
	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean
HHH	26.3	15.3	14.7	13.3	17.4	0.85	0.29	0.28	0.23	0.41	0.02	0.37	0.37	0.50	0.31	0 (0)	89 (100)	89 (100)	89 (100)	67 (75)	6.97	0.33	0.23	0.20	1.93	2.47	0.13	0.10	0.10	0.70
UPH	27.3	16.0	15.0	14.0	18.1	0.91	0.43	0.41	0.40	0.54	0.03	0.22	0.35	0.45	0.26	0 (0)	89 (100)	89 (100)	89 (100)	67 (75)	8.57	0.43	0.40	0.23	2.41	3.23	0.23	0.17	0.13	0.94
JHH	27.7	16.0	15.0	13.7	18.1	0.91	0.31	0.29	0.25	0.44	0.03	0.27	0.33	0.50	0.28	0 (0)	89 (100)	89 (100)	89 (100)	67 (75)	7.63	0.37	0.27	0.20	2.12	2.83	0.17	0.13	0.10	0.81
JJH	21.7	13.3	12.3	10.7	14.5	0.84	0.63	0.56	0.42	0.61	0.03	0.27	0.29	0.38	0.24	0 (0)	62 (78)	85 (98)	89 (100)	59 (69)	3.23	1.23	0.53	0.37	1.34	2.40	0.73	0.30	0.17	0.90
Mean	25.8	15.2	14.3	12.9		0.88	0.41	0.39	0.32		0.03	0.28	0.34	0.46		0 (0)	83 (95)	88 (100)	89 (100)		6.60	0.59	0.36	0.25		2.73	0.32	0.18	0.13	
	CD (P=0.05)			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*		*CD (P=0.05)*			*SEm*	
Biotypes	0.9			0.312		0.04			0.012		0.02			0.005		2			0.53		0.19			0.067		0.12			0.042	
Herbicide	0.9			0.312		0.04			0.012		0.02			0.005		2			0.53		0.19			0.067		0.12			0.042	
Biotypes × herbicide	NS			0.624		0.07			0.024		0.03			0.010		3			1.068		0.39			0.134		0.24			0.084	

Original figures in parenthesis were subjected to angular transformation. X dose is 140 g/ha; WAT, weeks after treatment, DAT, days after treatment.

9.3% lower plant height and 17.9% lower plant chlorophyll fluorescence than recommended dose, when data was averaged over all biotypes. As per the mean data over the herbicide doses, significantly lower EC was observed in JJH (0.24dS/m) followed by UPH (0.26dS/m), JHH (0.28dS/m), HHH (0.31dS/m). Complete mortality of weed plants was observed in JHH, HHH and UPH biotype even at 0.5X dose. However, mortality percentage in case of JJH biotype was comparatively less at 0.5X dose but total mortality was observed at 2X dose. All the biotypes were at par with respect to fresh weight and dry weight (g/pot) at X and 2X dose (Table 2). *Rumex* biotypes were found highly sensitive to halauxifen + fluroxypyr. Comparatively lower values of plant height, chlorophyll fluorescence, fresh and dry weight were observed in all biotypes. These results are in line with the findings of Prinsa *et al.* (2018) and Kumar *et al.* (2019).

All the four biotypes showed resistance against metsulfuron even at double of the recommended dose except JJH biotype where good control was observed at double dose. Higher values of plant height, chlorophyll fluorescence, fresh weight and dry weight and lower value of electrical conductivity was observed in the HHH, UPH and JHH biotypes as they have attained resistance against the weed. All the four *Rumex* biotypes were found highly sensitive to halauxifen + fluroxypyr at X dose. The good efficacy of this herbicide at recommended dose against all the biotypes collected from different locations provides an opportunity to integrate this herbicide in weed management options at field level for enhancing productivity of wheat.

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